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EXTERNAL DOSE RATES IN COASTAL URBAN ENVIRONMENTS IN BRASIL

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ABSTRACT

A long term activity aiming on assessing the exposure of the Brazilian population to natural background radiation is being developed at IRD/CNEN. Several research groups within IRD work in this activity, although mostly as a parallel work associated to main research lines followed by researches of the institution. One main activity is related to the raise of external gamma dose rates throughout the country. The objective of this work is to present results from recent surveys performed as part of the emergency preparedness for radiological emergencies during major public events in Brazil, such as the the World Youth Day, held in Rio de Janeiro in 2013, and the Confederations Cup and the FIFA World Cup soccer games, in 2013 and 2014, respectively. In this work, only the recent (2014) coastal urban environments measurements were included. Average kerma rates for Fortaleza is 80 ± 23 nGy/h, for Vitoria is 96 ± 33 nGy/h and for Angra dos Reis is 147 ± 16 nGy/h. These results are then compared to previous results on other coastal urban towns (Rio de Janeiro, Niterói and Salvador), and with the high background coastal area of Guarapari town.

1. INTRODUCTION

Very little information is available about external exposure due to natural sources of urbanized areas in Brazil. Historically, most data on exposures to natural background radiation reported in literature are related to high background areas. Very few information is available that allows the assessment of public exposure of the Brazilian population in a more broad way.

The first attempt to develop a collection of data in a geographic referenced database included only the routine environmental monitoring activities in the surroundings of nuclear installations in Brasil [1]. One important recent initiative was the development of the GEORAD [2], a system designed to collect and map the data raised throughout Brazil on environmental radiological surveys including literature data. This system made available a large amount of georeferenced data collected by several research institutions and universities in Brazil.

However, considering that most of Brazilian population lives in urbanized areas, most data for these areas in Brazil are related to results of radon surveys or to studys performed on high natural background areas. A project aimed on determining external dose rates in urban environments in Brazil is being implemented. The basis of the methodology was developed by Sachett [3], with focus on high background areas and the raise of more generalized information throughout the country is being performed by Maglhães et al [4], although as a parallel work using opportunities created by regular research and monitoring activities.

The objective of this work is to report recent results of surveys on coastal urbanized areas in the northeast and southeast regions of the country, where the dose rate surveys were performed mostly associated to the emergency preparedness plan for the World Soccer Championship held in Brazil on 2014.

2. METHODOLOGY

Measurements were done by car using a AT6101C Scanner - Spectral Radiation Scanner. The areas surveyed were not defined by any sort of priority assessment but the measurements are performed whenever possible, using trips done under regular IRD activities and survey programs.

In this work, the main areas surveyed were the towns of Fortaleza, Vitoria and Angra dos Reis. Additionally, data from Costa do Sauípe, close to Salvador, are also reported. Data from the surveys performed on Salvador, Rio de Janeiro and Niteroi were reported elsewhere [Magalhães, 2009] and statistical summaries are presented here only for comparative purposes.

The areas cited in this work are shown on Figure 1. Results were plotted with Google Earth@ to verify the type of area being measured in the map and statistical analysis was done with Wingraf@ software.

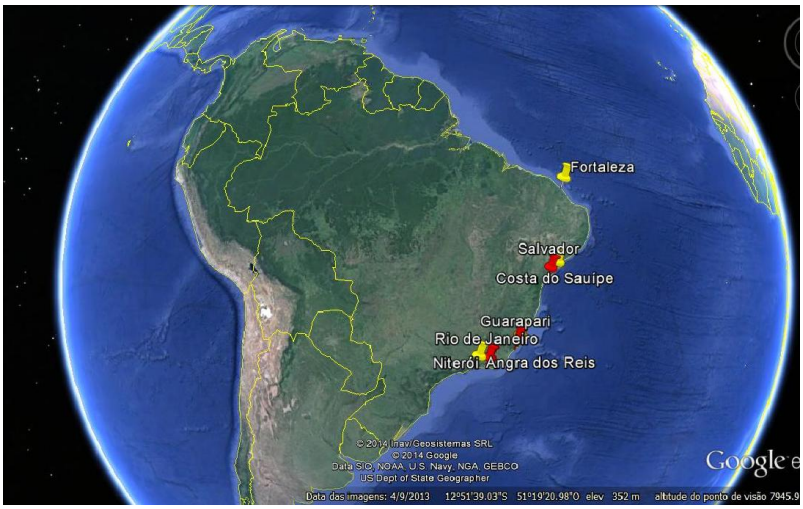

Figure 1. Areas included in this work (yellow) and those coastal areas already surveyed on previous works (red).

3. RESULTS

3.1 Vitória

Vitoria, the capital of Espirito Santos State, is a town with near 330 000 inhabitants. About 1400 measurements were performed according to the pattern shown in Figure 2. The distribution of results is shown if Figure 3.

Figure 2. Measurement pathwithin the town of Vitoria

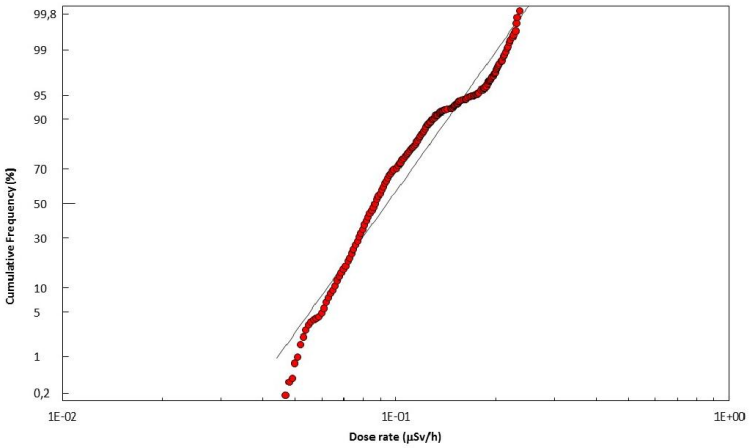

Figure 3. Distribution of measurements in Vitoria

It was possible to identify three different sets of measurements according to ther location characteristics. Smaller values were found at two parking areas, while higher values were measured in town islands (Figure 4). Statistical summary of measurements is shown in Table 1.

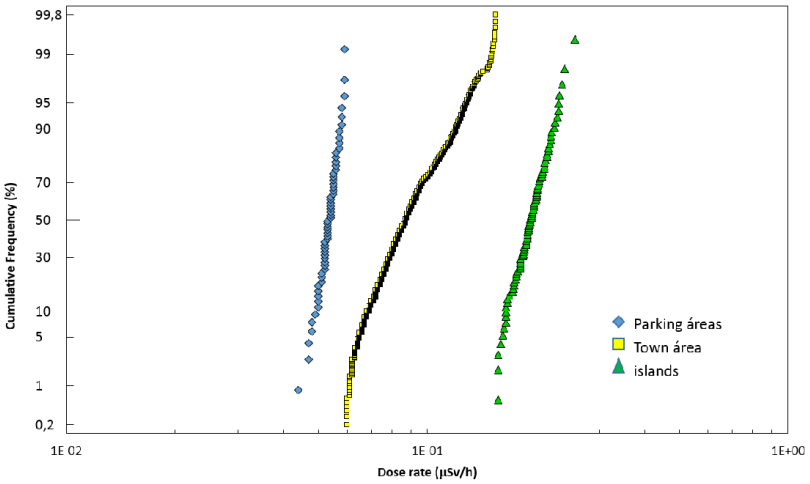

Figure 4. Different groups of areas within Vitoria.

Table 1. Statistical summary of measurements in Vitoria (nGy/h)

Group	N	Mean	Standard deviation	Geometric Mean	Geometric deviation	Minimum	Maximum
Parking areas	60	53,4	3,20	53,3	1,06	44	59
Other town áreas	1264	91,1	19,8	89,1	1,23	60	156
Coast of islands	87	194,7	21,4	193,5	1,12	157	257
All measurements	1411	95,9	32,8	91,5	1,34	44	257

3.2 Angra dos Reis

Angra dos Reis has about 185 000 inhabitants. The survey was done in the main town of the municipality and the path is shown in Figure 5. Distribution of results is shown in Figure 6 and the statistical summary is presented on Table 2. Measurements showed quite uniform values throughout the researched area, with a standard deviation of about 10% only.

Figure 5. Measurement locations at Angra dos Reis town.

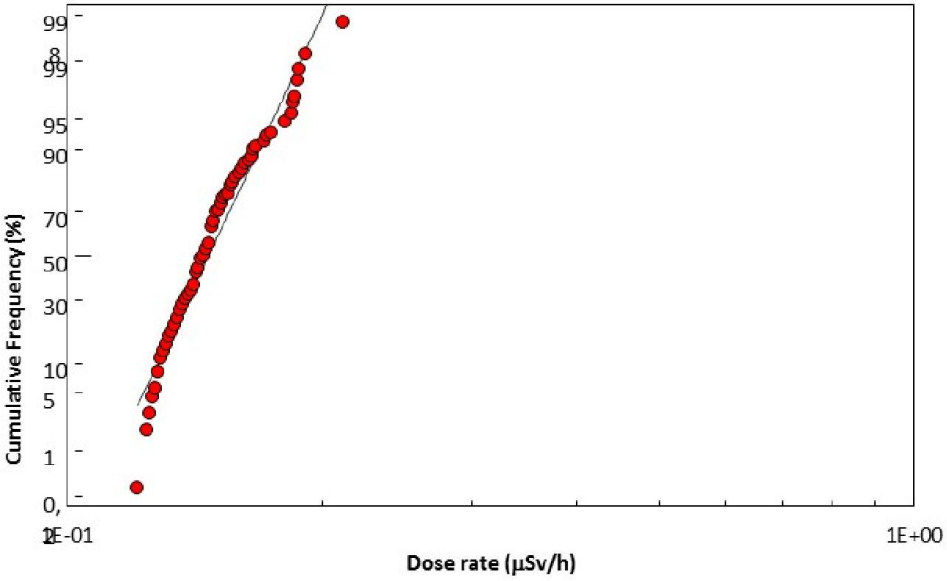

Figure 6. Distribution of values measured in the town of Angra dos Reis.

Table 2. Statistical summary for Angra dos Reis

Location	N	Mean	Standard deviation	Geometric Mean	Geometric deviation	Minimum	Maximum
All data	190	147,2	15,6	146,4	1,11	121	212

3.3 Costa do Sauípe

Costa do Sauípe is a touristic area North of Salvador, with large resorts but small number of permanent residents. The two main resorts were surveyed, according to Figure 7. Results distribution is shown in figure 8 and statistical summary of results are shown in Table 3.

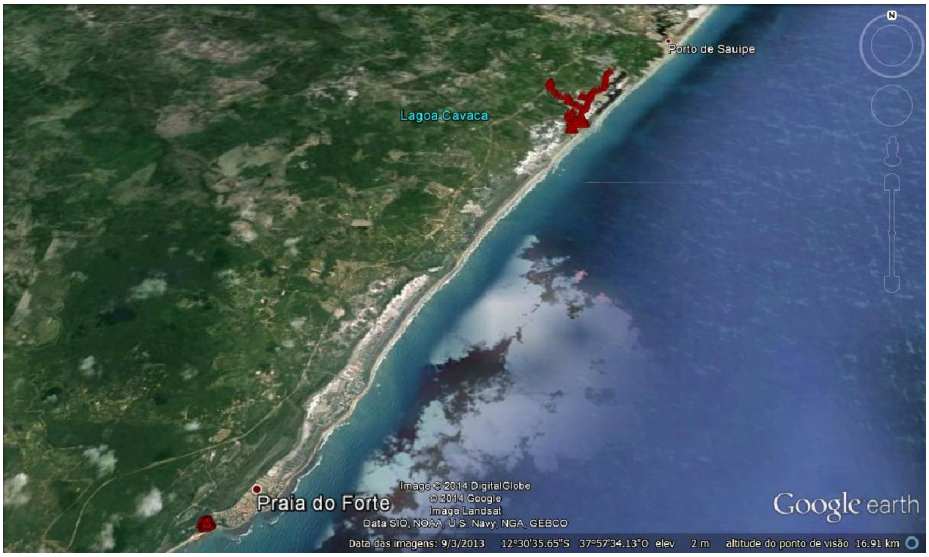

Figure 7. Locations surveyed in Costa do Sauípe

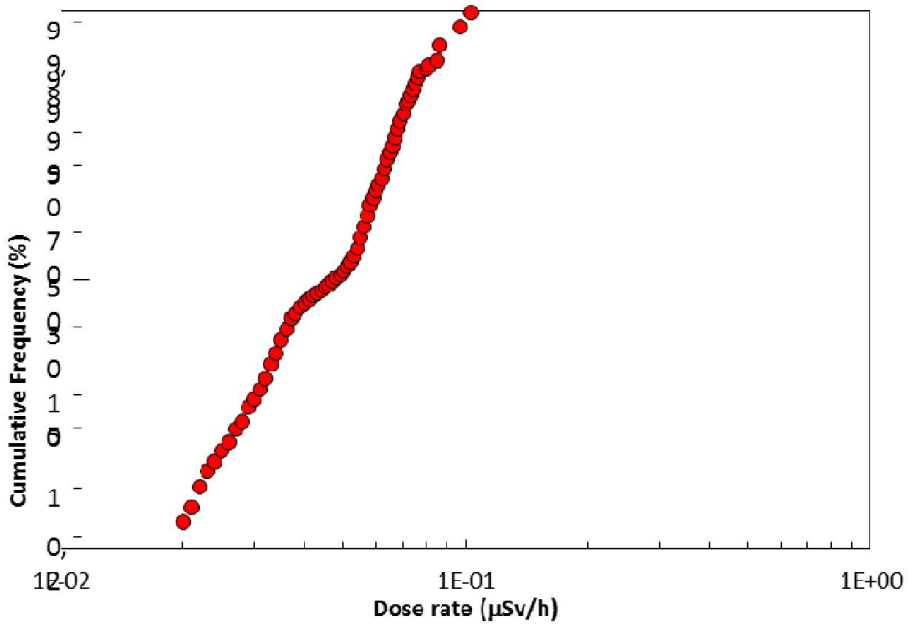

Figure 8. distribution of dose rate values measured at Costa do Sauípe

Table 3. Statistical summary for Costa do Sauípe (nGy/h)

location	N	Mean	Standard deviation	Geometric Mean	Geometric deviation	Minimum	Maximum
All data	1012	47,3	13,5	45,3	1,35	19	104

3.4 Fortaleza

Extensive survey was performed in Fortaleza in 2014. Fortaleza is the capital of Ceara State and has about 2.5 mi inhabitants. The detailed description of the survey is described elsewhere (Magalhães et al., to be published) and only the summary results are presented here. The measurement paths are presented on Figure 9 and summary results are presented on Table 4.

Figure 9. Measurent locations for Fortaleza

Table 4. Statistical summary for Fortaleza (nGy/h)

location	N	Mean	Standard deviation	Geometric Mean	Geometric deviation	Minimum	Maximum
All data	9824	80.0	22.5	76.4	1,37	19	190

4. DISCUSSIONS AND CONCLUSION

Table 5 presents a summary of available results for coastal areas in Brazil. Average dose rates vary from abou 40, in the state of Bahia, up to near 150, in Rio de Janeiro state. Population averaged external dose rate outdoors is estimated as 82 nGy/h, which is higher than the worldwide value of 58 nGy/h estimated by UNSCEAR.

In order to assess population exposure to natural background radiation, this type of survey should be extended to other areas, in particular to inhabited areas with more than 100 000 inhabitants.

Table 5. Summary of long range surveys of external dose rates in Brazilian coastal areas.

Town	State	Average (nGy/h)	minimum	maximum	Reference
Fortaleza	Ceará	80	19	190	This work
Sauípe	Bahia	47	19	104	This work
Salvador	Bahia	43	32	59	[4]
Vitória	Espirito Santo	96	54	257	This work
Guarapari	Espirito Santo	89[a]	26	5464	[3]
		83[b]	26	300	[3]
Niterói	Rio de Janeiro	105	75	151	[4]
Rio de Janeiro	Rio de Janeiro	96	75	126	[4]
Angra dos Reis	Rio de Janeiro	147	121	212	This work

a. Considering all measured data
b. Removing high background anomalies (> 300 nGy/h – about 1 % of measured data),

4. REFERENCIAS

1. Lourenço, L.F. ; Wasserman, M. A. **Implantação do Sistema de Informação Geográfica nas ações de pronto atendimento a emergências nucleares.** Relatório de pesquisa, Instituto de Radioproteção e Dosimetria (2010).
2. Silva, T.A.A.; Gonzalez, S.A.; Reis, R.G.; Vasconcellos, L.M.H.; Lauria D.C. GEORAD: sistema de gestão de dados de radioatividade no meio ambiente. *Regional Congress of IRPA on radiological and nuclear safety*, Rio de Janeiro, 14-19 Apr (2013).
3. Sachett, Ivanor Antonio **Caracterizacao da radiacao gama ambiental em areas urbanas utilizando uma unidade movel de rastreamento.** Tese (Ph.D.) Inst. de Biologia., Universidade do Estado, Rio de Janeiro, RJ (2002)
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